DOCUMENT RESUME

ED 182 790 CS 502 814

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TITLE Interactive Group Modeling: Part 3. HUB and the Modeling Process.
INSTITUTION Institute for the Future, Menlo Park, Calif.
SPONS AGENCY National Science Foundation, Washington, D.C. Div. of Mathematical and Computer Science.
REPORT NO R-46
PUB DATE Aug 79
GRANT MCS77-01424
NOTE 35p.; For related documents see CS 502 812-815

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS *Communication (Thought Transfer); *Communications; *Computer Programs; *Computers; Conferences; Futures (of Society); *Group Relations; Interaction; Networks; Research Projects; Telecommunication; *Teleconferencing

ABSTRACT

This is the third of four reports of the Interactive Group Modeling project--an undertaking designed to extend group communication through computers to support the more task-focused communication required by those building computer models. The report focuses on the HUB system--a system that facilitates communication in four modes: computer conferences, shared visual spaces, program workspaces, and document workspaces. Specifically, the report identifies potential roles of the HUB system in the modeling process and offers a preliminary taxonomy for mapping its uses. (FL)

INTERACTIVE GROUP MODELING:

PART 3. HUB AND THE MODELING PROCESS

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August 1979

Report R-46

This report was prepared under Grant No. MCS77-01424, National Science Foundation, Division of Mathematical and Computer Science. The project is under the direction of Hubert Lipinski and Roy Amara. Other staff members who contributed to this report include Roberta Edwards, Barbara McNeal, Jeanne Muzzicato, Robert Plummer, and Carol Westberg.

This report is the third in the *Interactive Group Modeling* series. The other reports are:

Part 1. *Extending Group Communication through Computers* by Hubert Lipinski, Robert Plummer and Kathleen Spangler Vian, Report R-44

Part 2. *An Interactive Monitor* by Kathleen Spangler Vian, Hubert Lipinski, Robert Plummer; and Sara Spang, Report R-45

Part 4. *Some Preliminary Tests of the HUB System* by Sara Spang, Barbara McNeal, and Kathleen Spangler Vian, Report R-47

The HUB User Guide, a manual for users of the HUB system

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HUB: A New Environment for Modeling

HUB is ready. The final pages of code have been written, implemented, and debugged. The *User Guide* is back from the printer's. The only question that remains is: What should we do with HUB now that we've got it?

HUB was designed to create a new environment for large-scale computer modeling. It is, above all, an environment for *group communication*. Like any computer conferencing system, the emphasis is on providing a "place" that a group of people can share--and a set of procedures that allow them to accomplish tasks jointly rather than individually. In HUB activities, there are transcripts to which all members of the group can contribute; there are opportunities to watch a group member run a program or make editorial changes in a document--and to discuss the best way to accomplish these tasks. The HUB program also provides other group-oriented information such as network patterns or simply status reports on how up-to-date each member of the group is.

Beyond its emphasis on group communication, the HUB system emphasizes *structured communication*--and a particular structure at that. The HUB environment is organized into activities, and different activities take place in different settings. Just as we wouldn't expect a basketball team to play basketball in their strategy room, we don't expect modelers to exercise their model in an electronic conference room. That's why HUB has several kinds of activities. If modelers want to discuss basic modeling objectives and strategies or coordinate their work over several weeks or months, then the relatively unstructured environment of a PLANET conference may be most appropriate. But if they want to write a program or run it under different conditions, they can move to a program workspace, which is designed for just that purpose. Or if they want to write a preliminary report to the client or develop a guide for maintaining and modifying a model, they can work in a document workspace. Of course, all of these activities are related, so it

should be easy to move both people and information among the various activities. This is the goal of HUB--to provide easy access to different communications settings "under the same roof."

A third characteristic of the HUB environment is the value placed on *interaction*. HUB *could* be used in a lecture-type style with one person generating most of the information and the rest of the group simply "viewing" this information. But HUB has been designed to facilitate interaction as much as possible. An example is the program workspace. In a program workspace, only one person can run a program at a time. But during the course of the run, other group members (see the interaction between persons and program) can send messages to the person running the program; and that person can send messages to the group. So the group can make joint decisions about the program run.

The HUB environment also supports *text-based communication*. Like other computer-based communication media, HUB requires the use of typed words to express ideas, opinions, and social meaning. But it also goes further than text-based communication to provide possibilities for numerical and tabular information. That is, through the program workspace--and specifically through the use of programs--people can communicate in a language other than their spoken language. In limited ways, they can also communicate graphically. (This capability for graphic communication will be greatly enhanced when the shared visual space is implemented in HUB.*)

Another feature of the HUB environment is the *permanence* of the communication. HUB maintains transcripts of the communication and work done in all of the types of activities. Thus, documentation--a problem that plagues modeling efforts--becomes partially automatic. Further, the document workspace supports the joint preparation of formal reports, which can draw on the material recorded in the other HUB activities. Records can also be modified or stored in private files outside of the HUB system.

This record of communication, combined with HUB's ability to recognize who has seen what information in an activity, creates a *flexibility of time* in communicating via HUB. As in most computer conferencing systems,

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*For a description of the plans for the shared visual space, see Hubert Lipinski, Robert Plummer, and Kathleen S. Vian, *Interactive Group Modeling, Part 1: Extending Group Communication through Computers*, Report R-44.

communication can be synchronous or asynchronous. Members of a modeling team can work when it is most convenient for them; they can also catch up or comment on the work of others at their convenience. For example, although they may not want to stand around while one of their colleagues is changing the A-matrix values in a KSIM program,* they could want to make suggestions about what those changes might be. And they certainly would like to see the results, comment on them, and possibly try out changes of their own. They can do all of these things asynchronously--when they are online alone.

Finally, the HUB environment is a geographically dispersed environment that encourages use of *remote resources*--both human and computer resources. Since HUB is implemented on a network, modelers using the system can gain access to a wide variety of programs and data bases on a variety of computers without having to leave a single program workspace--and without having to leave the *communication* capabilities of HUB. Furthermore, the modeling team can include people who are geographically separated. HUB not only allows them to coordinate their work with each other, but also allows them actually to *work* together.

All of these characteristics create a working environment that is different from the ones in which models have been designed, built, tested, and presented in the past. It would not be surprising, then, to find that models developed using the HUB system are different from other models or that the way they are developed differs from the ways they have traditionally been developed. The question that we posed earlier, though, still remains. How should HUB be used? What kinds of modeling efforts are most likely to benefit from the features found in the HUB environment? How might they be best organized? And what will be HUB's impacts on the model itself?

In the following pages, we explore the possibilities for using HUB in the modeling process. We have selected four examples of promising uses--not uses that have been tried and tested yet but uses that we think *should* be.

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*See Hubert Lipinski and John Tydeman, "Cross-Impact Analysis--Extended KSIM," *Futures*, vol. 11, no. 2, April 1979.

Promising Uses and Possible Impacts

To analyze any modeling effort, we start by asking three simple questions:

What is being modeled?
Why is it being modeled?
How should it be modeled?

Every modeling team has answers to these questions, whether or not its members ever state them explicitly (and whether or not the answers they state explicitly are the real answers!). But for different modeling efforts, one or another of these questions will be the most important. Some efforts will focus on clarifying the nature of the system to be modeled without questioning its possible end uses and without any commitment to any particular modeling approach. Others will start with an objective--very often an organizational rather than analytical objective--and design the model *as well as the modeling process* to meet that objective. Still others will start with a methodological question and select the "what" and "why" of the model to test that methodological question.

In looking for promising uses of the HUB system, we have sought a range of possibilities that (1) emphasize different questions as starting points and (2) might really benefit from one or more of the HUB features. In this chapter, we describe four of these possibilities. The first is one in which the question of "what" is foremost; in fact, the purpose of the modeling effort is to define what the problem is. The second and third possible uses are "why" examples. The second is an effort to use modeling specifically to improve communication among actors in a situation. The third also focuses on a communication need: the need for policymakers to have better tools to help them in decision-making. This emphasis on applied use of the model raises one of the most troublesome problems in modeling management--documentation. Finally, the fourth possibility is a "how" example. It is primarily a methodological study concerned with ways of linking models together.

SCENARIO 1: WHAT ON EARTH IS THE PROBLEM?

Things are a mess!

There are gas lines, and meat prices keep climbing. The American family is falling apart. Television is boring, and nothing new is happening in music. It's July, and the potholes in the streets from last winter still haven't been repaired.

This is the environment in which most decision-makers have to operate today. Sometimes, it is relatively easy to isolate *the* problem to be addressed by the decision-maker. But often "the problem" is so complex and many-sided that the most pressing problem is to figure out what the problem is.

This process of problem formulation or definition is itself a process of modeling. It is a process of generating issues or variables that constitute the problem space and of identifying relationships among these variables. Unlike many modeling problems, however, problem formulation stresses *expansion* of the list of variables, since the objective is to construct the richest possible picture of the problem situation. And the specification of relationships among variables is not so much to predict outcomes or even to understand the operation of the system, but rather to gain an appreciation of the diversity of perspectives about the problem situation. The problem formulation that emerges out of such a process is likely to be seen as more relevant to decisions of many key actors than a problem statement that is made prematurely or arbitrarily.

Such a problem formulation process emphasizes group communication; to expand issues and obtain a diversity of perspectives requires input from many people. It also requires some structured communication in order to organize the many variables and perspectives. For these reasons, we think HUB has some promising applications in problem formulation, as suggested by the following scenario.

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The situation is this: a state agency has contracted with a consulting firm to aid it in defining what kind of research would be most useful in planning not only its budget and staffing, but also possible changes in its services and overall organization over the next five years. The project has the enthusiastic support of a high-ranking official in the agency, who has convinced members of all of the regional offices to participate in the study. The charge to the client is to develop an effective procedure for them to jointly define their research needs. The agency doesn't want the process to take a long time--six weeks at most--or to be too disruptive of the day-to-day responsibilities of the regional participants.

This is the way they might use HUB: the consulting firm begins with a quick series of face-to-face interviews with each of the participants from the agency in order to gather their impressions of the major issues the agency will need to address over the next five years. The interviews also enable the consultants to get to know the participants. Next, they establish a PLANET conference in HUB to feed back the issues (anonymously) to the entire group. Over the next week, the group discusses these issues and finds that, as a result of the discussion, the number of issues has more than doubled. At the same time, the consulting group has interviewed representatives of several outside groups with an interest in the agency, identifying issues that they feel are crucial for the near future. These issues are also presented and discussed in the PLANET conference.

From this initial list of issues, the consulting team selects a number of variables to be structured in a forecasting model. The team sets up the program for the model in a program workspace, demonstrates its use, and encourages the rest of the group to experiment with different values and relationships for the variables as well as with different variables. Some of them do this jointly, some do it individually, and others just watch. This generates discussion, both in the program workspace in connection with specific runs and in the PLANET conference that is still running.

At the beginning of the fifth week, the consulting team invites the participants to begin to list their ideas about research needs. The team takes this joint list, together with a preliminary survey of related research already completed, to a face-to-face meeting with the group at the end of the sixth week.

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An obvious benefit of HUB in this situation is a practical one: a group of people in several different locations can work jointly on a problem over a period of six weeks without severely disrupting their work schedules. From this practical benefit flow the intellectual benefits of more time to reflect on the work being done, more immediate responses than might be possible with a series of face-to-face meetings, and the opportunity for an interplay between the ideas being discussed in the conference and immediate events taking place on the "home turf" of each of the participants.

But more significant is the capability of HUB to provide a focus and structure for comparing perceptions and assumptions about the problem situation for the agency. In this case, the structure was a forecasting program.* We expect that the various runs of the program would bring a number of inquiries about the rationale, about the assumptions behind particular choices of variables or values for variables. Similarly, the results of the runs should prompt discussion of various interpretations. Of course, they will most likely also lead to some new learning about the users' environment--the program can display relationships and consequences of relationships that are difficult to conceptualize in one's head. It might even produce some surprises that suggest entirely new issues or ways of viewing the environment. The use of such programs *in the context of group communication* could produce intellectual insights as well as foster a common group understanding of the process being modeled.

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*For a summary of some of the structural modeling tools from which such a program may be drawn, see George G. Lendaris and Wayne W. Wakeland, "Structural Modeling--A Bird's Eye View," Portland State University, Systems Science Program, February 1977.

HUB offers some other minor benefits in this situation. For example, its recordkeeping capability would allow the group to review ideas continuously--a capability that is probably useful in any brainstorming situation. Also, as used in this scenario, it provides some initial anonymity in the listing of issues, and such anonymity can also promote less inhibited participation in brainstorming.

At the same time, though, we suspect that there are a number of things that could go wrong in this use of HUB. Problems of participation are most likely. Using any computer conferencing system requires a commitment to the group and a perceived need to communicate. The opportunities for a lack of such commitment seem plentiful in the situation we have described, although it helps to have a high-ranking official fully behind the effort. But beyond the inherent passiveness of a computer-based system, the use of any forecasting program may be intimidating to some members of the team. The ability of the consulting team to teach the group to use the program is critical; if some members feel unsure and insecure, they might simply drop out or sabotage the whole conference in some way. Participation does not necessarily mean running the program, though. Some people may choose to comment on runs and offer suggestions and thus remain active participants without actually doing their own runs.

Another potential problem is that the discussion in HUB is so different from face-to-face communication that participants may become frustrated by a feeling of information overload and be unable to extract any learning from the process. The PLANET conference certainly has the capability to promote mushrooming, nonsequential ideas--hence its value for brainstorming. However, the group needs to be patient with this process. One consolation, of course, is that subsequent runs of an interactive forecasting program should help to structure some of those ideas. But what if they don't? It is possible to imagine that the group members might all end up going off and running the program by themselves without ever reviewing and commenting on other runs. Then they would not only not know how others were interpreting the relationships; they would not even know what runs the others had seen.

Finally, it may be difficult for the consulting team to find the right level of control over the conference. On one hand, it would be a mistake for them to let a situation such as the one we just noted arise; on the other hand, a lot of the learning and communication will probably occur as a result of the freedom for the group members to explore the program workspace on their own. And this freedom could be a little threatening to the consulting team, particularly if it has doubts about the value of its own contribution and the process it is promoting.

In the next two years, as we test NUB in situations like these, we will want to watch to see if our anticipated benefits or problems emerge. We will want to pay particular attention to the strategies that seem to promote the benefits and avoid the problems.

SOME OTHER PROMISING USES OF HUB FOR PROBLEM FORMULATION

- *Use of the program workspace to compare alternative "structures" of the problem situation.* There are a wide range of general-purpose modeling packages (such as KSIM, ISM, ASSESS, among others) that can be used to develop a structure for the problem situation. Rather than explore different variables and values for variables, as was described in Scenario 1, a group might select a limited set of variables and use those variables in a variety of different structuring programs. Discussion would focus on the different relationships that might emerge using these different programs.
- *Use of the PLANET conference to identify issues.* The initial definition and structuring of a problem often involves the input from a number of professionals. The PLANET conference provides a way for people who are geographically separated, or who are unable to meet simultaneously, to generate issues and structure relationships among variables.
- *Use of the program workspace to test model structure.* The program workspace enables model builders to test working sub-components of the model, to relate results to the postulated problem structures, and to test the sensitivity of changes in parameters. It is possible to comment and assess simultaneously as the model undergoes changes.

SCENARIO 2: SPEAKING THE SAME LANGUAGE

There are lots of reasons for building a model: to provide assistance in planning, to develop skills in conceptualizing a complex problem, to influence the way others see the world, to explain phenomena that have not previously been explained. All of these reasons suggest the need for some communication, even though communication may not be the primary motive for the modeling effort.

Improving communication among the principal actors in a situation may, however, be a focal reason for modeling. The modeling process forces participants to make some of their assumptions about the world explicit. In simplifying reality, as all models must, the participants point to those elements which seem most important to them. In assigning values to variables or preparing data for input, they get a more detailed understanding of how each of them is viewing the world. By running the model with different values for variables, they come to understand how important or unimportant differences in perceptions about those values are to the outcome. And by jointly working on a common task, they provide at least a foundation for a continued working relationship beyond the modeling effort.

At the same time, the key actors probably do not have the skills to build a model themselves. If they hire a group of modelers to build the model, chances are that a lot of those decisions which should provide the basis for improved communication will be made by the modelers and one or two of the actors who are working closely with the modelers--or simply by the modelers themselves. Furthermore, the group might then be asked to "buy into" the model without really knowing what it is or why they should trust it. As a result, the modeling effort actually becomes a barrier to the communication process.

HUB could help this situation in several ways: it could be used much the way we described in Scenario 1, in the problem formulation stage, using general-purpose modeling packages. It could also help by providing improved

documentation, as will be described in Scenario 3. But a real innovation in the modeling process might be to make the entire model much more interactive, leaving room for the key actors to make more decisions as the model is running. In form, such a model would be like a simulation game, except that the "players" would have much more control over the rules and much more knowledge of the roles than in typical simulation games. This promising use of HUB might unfold as follows:

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The situation is this: *two divisions of a corporation are examining the possibility of sharing some of their resources, including warehouse space, transportation facilities, and data processing services. While upper management believes that such a change would result in lower costs and reduced energy needs, they also anticipate a lot of resistance from middle management. Thus, they have hired a team of analysts to develop a model to help them plan for the new system. Assuming that the middle managers will be more enthusiastic if they help plan the system, upper management asks the team of analysts to involve four key managers from each of the divisions in the process.*

This is the way they might use HUB: the team develops an interactive simulation in two stages. The first stage models the existing systems in the two divisions. Each manager is consulted in a face-to-face interview in this process, and the progress of the modeling effort is reported in a PLANET conference to which all of the managers have access. The resulting two models can be exercised by the managers. The exercising consists of running each model in a program workspace; since the managers are online at the same time, they make decisions individually or in teams at various points in the program run. Discussion focuses on the results of the runs and the allocation of decision-making responsibility.

The second stage attempts to model the conversion process. The modeling team and the managers do this jointly. As the managers of one division make decisions that affect the operation of the other division, the model builders begin to construct links that describe the effects. This is accomplished asynchronously over a period of several weeks. The result is

a third model that represents a combined system and that can be exercised much the way the first set of models was, only with all managers participating together. Here, the discussion focuses on unforeseen problems and opportunities as well as on the identification of areas in which cooperation or clarification of responsibility and authority will be needed. It also provides an overview of the types of decisions that each of them must make that they would not normally anticipate. Based on this discussion, they develop a set of recommendations regarding the best procedures for implementing the changeover.

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HUB provides a unique and fundamental advantage for this kind of modeling effort--the ability for a group of geographically separated people to interact with a program. This easy-to-use interactive capability means that joint human-computer simulation of a process is encouraged. The human players can thus become participants in the formulation of the model, with a better understanding of the model's assumptions, as well as each other's. The model builders can construct the model on the basis of the kinds of decisions the humans make rather than predefining the kinds of decisions the model can deal with. In short, it is a very different way of doing modeling.

Beyond this ability to involve the decision-makers in the modeling process, HUB creates an environment in which a group such as our fictitious managers can learn not only about the system being modeled, but about their relationship to the system being modeled. They can see who is called upon to make decisions, the kinds of decisions they need to make, and even the motivations for those decisions. They can see the relationship between their own decisions and those of others. And since all of this occurs in a context of group communication, they can discuss what is going on.

The ability of HUB to support communication among geographically separated people is, of course, fundamental since, in this scenario, we have actors in at least three separate locations.

HUB's ability to support both synchronous and asynchronous communication is also important in this scenario. We expect the synchronous model to be ideal for exercising a simulation model with a group of decision-makers; in a very short time, they can raise many of the issues regarding the operation of the system and their own decision-making processes. At the same time, the asynchronous mode is critical to the model builders, who need time between decisions--or runs of the developing model--to construct and modify the model.

This time flexibility could be a problem, however. It would be easy for managers to lose interest in the process if several days and much discussion were to come between their decisions and the computer's interpretation of their impacts. And since the computer doesn't beckon them when it's time for a new decision, they may just not come back.

Another problem might arise from the game-like quality of the modeling process. A model can never match the real world in complexity; thus, the simulation could appear oversimplified, and the managers might not take it seriously. They might even feel that it is undignified and be reluctant to participate. Alternatively, they might "play the game," but treat it as a game and not make decisions that are representative of their decisions in real life. In either case, it is important to discuss those parts of the model which seem oversimplified rather than letting the group ignore them.

The dynamics of such a modeling process will inevitably reveal a lot about the interpersonal relationships among the managers, and some of these relationships may need improvement. That is, after all, one of the primary purposes of the exercise. However, the managers may be reluctant to address these interpersonal issues in the presence of an outside team of analysts. Perhaps even worse would be a tendency to use the modeling team as process consultants: most modelers are hardly qualified to assume such a role!

Finally, while a simulation game is less threatening than a formal meeting, it can still be threatening if the managers feel that they are somehow being tested, particularly in the presence of their peers. If the exercise is to promote communication among them, then, *someone* is going to have to do *something* to establish an atmosphere of trust.

SOME OTHER PROMISING USES OF HUB FOR PROMOTING COMMUNICATION

- *Use of a program workspace to promote communication among experts in a field.* A group of experts could be invited to "exercise" one or more models in a program workspace. The runs would emphasize alternative values for variables, with discussions of the assumptions underlying those values. While the actual model runs might yield some insights about the sensitivity of the model to alternative assumptions about values for the variables, the real major objective would be to increase the experts' understanding of one another's assumptions and world views, and perhaps to encourage some synthesis.

- *Use of PLANET and program workspaces to promote communication between the model builder and the client.* The HUB system might be exercised much as just described. A newly developed model would be exercised by a group of experts, together with the model builders and the client. Such a use would (1) allow everyone to discuss the alternative values for important variables; (2) allow the group to test the sensitivity of the model to variations in values that are particularly interesting to the client; and (3) provide the client with a critique of the model by the experts.

- *Use of the program workspace to train future users of the model.* If the model is to be run and maintained by a group other than the model builders, the program workspace could be used to train these users. They could participate in trial runs, with the builders observing and commenting on their runs as appropriate. This process might also suggest particular documentation needs that might have gone unnoticed.

SCENARIO 3: WE'VE GOT PEOPLE DIGGING THE RIVER FOR CLAY 12 WATCHES A DAY!

One of the most disappointing failures of large-scale computer models has been their lack of impact on the policymaking process. This failure has many possible causes. But the one that is cited most frequently is the lack of adequate documentation.*

The proposed solutions to this problem have been *standards* and *discipline*. The Department of Defense has answered the call for standards by producing a lengthy volume of specifications for the documentation of computer programs. Since people are wary of the natural ability of modelers (or anyone else) to exercise self-discipline, it has been proposed that one or more members of a modeling team be included solely to document the effort.

It seems clear that many modeling projects will not take such a formal approach to documentation. In fact, such an approach to documentation might conjure up a scene in a recent science-fiction spoof of computers and communication technology. In it, novelist Rob Swigart transports us back to the days of Gilgamesh in Sumeria and suggests some of the problems that Gilgamesh might have had meeting DOD-like specs for documentation:

> "I look glum, huh? Well, I am glum. You got me started on this damn recordkeeping and filing and listening to complaints and all the rest of this stuff, and frankly, I'm going nuts. The gods hate me and won't talk to me anymore. I haven't heard a thing from Lugulbanda since last week. I spend all my time reading these damn reports. So much barley here, so much wheat there, so many *es* of walls built, so many *es* fallen down, so many *iku* of grain planted, so many harvested, so many spears and bows and arrows and helmets in the warehouses, so many *es* of canals broken down and not repaired, so much grain eaten by rats. Do you realize that since we started this recordkeeping, the scribes have filled four huge rooms with clay tablets, and that's this month alone. And here" -- he waved his elbow at the litter on

*See especially Saul I. Gass, *Computer Model Documentation: A Review and an Approach*, University of Maryland, College of Business and Management, April 1978.

the table. "Notes! I use up tons of clay just taking notes. I've got people digging the river for clay twelve watches a day, sunup to sunup, and we still can't seem to collect enough clay. It's awful. Ouch!" He had put his elbow down on a jagged piece of clay.*

Modelers don't have to worry about scraping their elbows on a jagged piece of computer code, but they do need to keep documentation efforts from running away with the modeling project. Our third promising use of HUB concerns this need.

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The situation is this: *a team of four is building a model that involves an extensive regression analysis to develop a set of equations for forecasting future patterns of use of national forests. In all, they will probably need over 75 "runs" of the regression program. Different members of the project team will be making the runs at different times. They will need to keep track of who has run the program, which variable combinations were tested, what the results were, and what new runs the results suggested; then they will need to record this information for the client and select and label the significant runs for an interim report. Since all of the team members have other project commitments and will be traveling off and on during this process, they will have trouble keeping up, on a daily basis, with the progress of the runs; they will also have some difficulties discussing the results and next steps. And since they are human, they are likely to become inundated by stacks and stacks of computer printouts that are incompletely labeled or not labeled at all.*

This is the way they might use HUB: two activities are set up. The first is a travel conference in PLANET. This is used whenever one of the project team is traveling to coordinate the project or for general discussions about the regression analysis. The second activity is a program workspace in which the regression program can be run. The group agrees to one protocol in running the program: that at the beginning of each run they will include a brief comment describing the run. Thus, whenever the team

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*Rob Swigart, *The Time Trip*, Boston: Houghton Mifflin Co., 1979, pp. 151-52.

members want to know the status of the regression analysis, they check into the program workspace, HUB indicates with an asterisk which runs they haven't seen, and they review these runs, using the "COMMENTS ONLY" restriction, so that they obtain a listing of the runs plus the initial comments that describe the runs. For example:

Regression [23] Run by Smith 7-Aug-79 9:30 AM

[Comment 1] Smith
This run will concentrate on the variables DISCRETIONARY INCOME and OIL PRICE. They will be forced in the first regression step, and we can see what r squared results. It will also be interesting to see the order in which the other variables are chosen in subsequent steps.

Of course, they sometimes also want to see complete transcripts of some of the runs and comment on them. When all of the regressions have been run, one project member agrees to document the work. Using the document workspace, she prepares a brief report outlining the approach that has been taken and the assumptions underlying it. She includes an overview of the regression runs and the conclusions that have been drawn from them. To this report she appends a list of all runs with comments and the entire transcripts for the 10 critical runs. The report is then copied and placed in notebooks for a face-to-face meeting with the client before proceeding to the next step.

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HUB seems promising in this situation for several reasons. The first is that it tends to capture documentation information at the time of the run. The user has to enter the HUB program workspace in order to use the program. Commenting on the run then involves the same kind of behavior as running the program--typing at the terminal, waiting for prompts from the system, and responding. Documentation becomes a more natural extension of the run itself and is thus easier; it is also more likely to capture the immediate thoughts of the person doing the run, rather than requiring that the user reconstruct them minutes, hours, or days later. Furthermore, this information is juxtaposed to the run--or even the portion of the run--to which it refers.

HUB also captures some information automatically, even if the user does not provide comments. It captures the run transcript itself, together with the time and date it was run as well as the name of the person who ran it and a run number. It thus provides an automatic filing system, from which transcripts can be retrieved by date, by number, or by author name. (It is also possible to retrieve by keyword if that is appropriate.)

The same features that provide this easy-to-access transcript file also make it possible to obtain a quick overview of what has been done and by whom. This makes the system a useful management tool as well as an aid in preparing summary documentation for a client, as suggested by the scenario.

Finally, HUB provides a document workspace in which reports can be prepared. Here, as in the program workspace, there is emphasis on group interaction and collaboration. All group members can comment on a document or edit it and explain their changes. Each time a user enters the workspace, all changes that he or she has not seen, along with explanatory comments, are automatically displayed.

Now, what could go wrong? Obviously, users might not be motivated enough to meet even the minimal requirement of one comment at the beginning of the run. In some cases, they might even choose not to store a run (this is possible in HUB) because they feel it was insignificant or perhaps contained an error that was embarrassing in some way. Information would certainly be lost in this case, but the loss is no more likely to occur than in traditional ways of running programs and documenting runs.

The situation could, however, be worsened if the system led to *misinformation* rather than just the loss of information. For example, if comments were not clear or not adequate or if there were unrecognized misunderstandings about the terms being used, misunderstandings about the analysis itself might result. Some runs might be duplicated, while others might be omitted. Or the wrong run might be selected for constructing the equations. This situation would be even more troublesome if the group placed too much faith in the "systematic" quality of the HUB process.

Also, the group might be seduced into placing too much confidence in the ability of HUB to capture the really important communication about the

runs. In fact, the most important discussions--the ones that lead to decisions--are likely to occur face-to-face or even over the telephone. This is okay. No one expects modelers to take up permanent residence in HUB. But if modelers think that they are automatically gathering all of the important decisions, they may neglect to record some vital information *outside* the system.

Finally, we can speculate that all of this recordkeeping might make some members of the project team a little nervous, a little resentful, or both. After all, if one person has done more than two-thirds of the runs when the workload is supposed to be shared equally, the inequities are going to show up. Differences in skill levels may show up, too, and discourage some people from participating. In such cases, HUB may inhibit communication more than promote it.

OTHER PROMISING USES OF HUB FOR DOCUMENTATION

- *Use of a program workspace as a personal workbook for exercising a program or model or for developing a program.* The use would be similar to that outlined in the scenario just described, except that it would be a personal record rather than a group conference.
- *Use of the document workspace as a personal notebook.* Each member of a modeling team might want to maintain a set of personal notes about the project. These notes might include questions to be raised, ideas concerning later stages of the project, and the kinds of notes one often jots down on the backs of envelopes during the course of a research effort.
- *Use of a PLANET conference by geographically separated members of a project team to document assumptions about the model.* The PLANET conference might be used to conduct a general discussion of the variables and their relationships as well as other models of the same process. The conference organizer could then analyze the transcript to identify assumptions. These could be listed for the group to comment on explicitly. With revisions, they could be included in a report to the client. (The client might even be included in such a conference.)
- *Use of the document workspace to write, modify, and annotate code and to document assumptions made by programmers in the course of implementing a model.* Since the document workspace is designed for joint editing, it may actually encourage joint programming as well as a record of changes in the code, together with reasons for those changes. Often programmers realize that they have to make some assumptions that were not specified by the modeling team as a whole. As these occur, they can be noted in the code, and memos can be prepared for group discussion.

SCENARIO 4: THE EMPIRICAL LINK

HUB is first and foremost a communication environment. But it is also a laboratory in which experiments can be conducted--experiments in modeling methodology. With its capability for structured group communication and its automatic recordkeeping capabilities, HUB provides an ideal setting for exploring empirical approaches to some of the problems that confront modeling today.

An example is the linking of submodels. This process, which is one of the critical issues in large-scale modeling, can be viewed as a process of building communication channels among the submodels. The effectiveness of the composite model will depend on the characteristics of these channels. Some of these characteristics will be technological: How is the information transmitted? How quickly? How frequently? Other characteristics of the communication channel are more cultural. When the output of one model is not exactly what is required as input to another, then interpretation of the output is required. How is this done? How does it depend on the background and views of the person who is linking the models? The way that these questions--both technological and cultural--are answered in linking submodels will depend on three considerations:

- First, there are *theoretical* considerations. A good example is the question of how a time-dependent model should logically be linked to a static model.
- Second, there are *software* considerations. Software choices for the individual models will inevitably constrain the type of link that is constructed. Software capabilities, in general, will shape both the technological and cultural characteristics of the communication channel.
- Finally, there are *interpretive* considerations. When no automatic link exists between a pair of submodels, a user of the model must

interpret the results of each in the light of the other. This is a highly selective process, which varies from user to user. When the communication channel is constructed, it must provide some means for this kind of selection and interpretation.

The HUB environment provides a particularly good opportunity to examine the interpretive process empirically and to construct links based on the results of this observation. The following scenario suggests how such an empirical approach to linking submodels might proceed.

* * * * *

This is the situation: a team of modelers, social scientists, and computer scientists is working on an experimental project to develop a methodology for linking submodels. They want to use an empirical approach, observing how different groups of human users of the models interpret, synthesize, and use the information in various submodels and then identifying procedures for doing this automatically via computer.

This is the way they might use HUB: the team establishes several program workspaces. Each of these workspaces includes two or more submodels (of varying complexity) that are to be linked. The tests involve use of the submodels by a variety of different subjects who range from lay people to social scientists and experienced modelers. In each test, one or more people are first briefed in a PLANET conference. They are given problems to solve that require using information from all of the submodels in the workspace. Sometimes the tasks call for using information from one or more submodels in running another, but this integration of models may require considerable ingenuity and interpretation.

The analysis of the tests includes: (1) using the HUB interactive monitor to track the flow of information, (2) content analyses of transcripts of the runs in the program workspaces to find commonalities and differences in the way the subjects approach the problem, and (3) direct questioning of subjects as they are running the program to discover why they make the choices they do and how they perceive what they are doing. The objective is to observe the types of operations the human "links" perform

in transferring information from one model to another and thereby to arrive at some understanding of what part of that process can be automated and what rules should guide the automation.

* * * * *

HUB provides two distinctive benefits for this kind of experimentation with modeling methodology:

First, it allows the research team to structure the experimental setting, controlling access to resources and providing the same information to all of the subjects. At the same time, this structure is easy to use; thus, differences in the approaches of different subjects will have less to do with skills in using computer programs than with their different perceptions of the problem and the possibilities for solving those problems.

Even more critical to the experimental setting are HUB's capabilities for monitoring the flow of information among participants and programs in the workspace; its automatic recordkeeping capabilities that provide complete records of the *substance* of the information exchange; the opportunities for unobtrusive observation, so that the researchers can note subtleties that may not be captured by the transcripts or monitor data; and the opportunity for obtrusive observation--that is, to interact with the subjects as they are performing the assigned tasks.

The problems with the HUB environment are much the same problems that occur in any experimental setting. First, the tasks and setting are artificial; the approaches to solving the problems, and the communication patterns in particular, are likely to be somewhat artificial also. If the experimenter's purpose is to identify the cultural considerations in linking submodels (or any other modeling problem), he or she should be aware that the HUB system changes the culture of the subject.

The observation capabilities that are a benefit to the experimenter are also a possible liability. Subjects in all experiments tend to perform for the observers. And even though the observers may never interact with the subjects, HUB is always reminding the subjects that someone is or is not present.

Finally, the HUB environment may itself constrain the possibilities for the way the subjects transfer information from submodule to submodule. The program workspace does not give them access to the full power of the computer--power that certainly would be available to the modeler or computer programmer constructing a link. Thus, the human linking processes observed may demonstrate the way that models can be linked in HUB more than the best way to link models.

SOME OTHER PROMISING USES OF HUB FOR EMPIRICAL DEVELOPMENT OF MODELING METHODOLOGY

- *Use of the program workspace to develop a representation of a complex decision-making process.* A preliminary model program might be run in a program workspace. One member of the modeling team (or test subjects) would run the program, suspending it at various points to ask for information and to make decisions. Other members of the team might then analyze these decisions in terms of the points at which the decision-maker stops the model, the types of information sought, and the complexity of the decision. This analysis would guide them in formally representing the decision-making process.

- *Use of the program workspace to test an "intelligent" model.* There has been some work to include in simulation models a representation of an "intelligent" policymaker's perceptions of the world and his or her creative responses. Such a model might be tested in a program workspace. The model could be run with different configurations for the perceptual/problem-solving module. The performance of these various configurations could then be compared to that of (1) an individual human actor presented with the same information; (2) a group of human actors; and (3) a group of human actors who have been given specific political or bureaucratic roles to guide their decisions.

- *Use of the program workspace to analyze the structure of a model.* A model program could be included in a program workspace with a series of programs that detect and analyze the structural features of the model. For example, one program might analyze the strength of every feedback loop in the model; the group could then discuss whether or not these loops seem plausible and represent mechanisms that can be explained in the real world. If not, they can "mock up" changes in the model and test the new structure.

Modeling Choices: A Framework for Evaluation

This report has outlined some uses of HUB that we think are promising. These uses range from ones that are immediately and practically attractive to ones that are more exploratory and require some real risk-taking. They all reflect what we believe to be the strengths of the HUB system for the modeling process.

Over the next two years, we will be testing HUB in field settings. We hope to have the opportunity to observe its use in situations like those described in the scenarios. But we also recognize that there may be other situations in which HUB is as useful or more useful. To evaluate these situations, we need to place them in some framework, to locate them on a kind of map of the modeling world.

How do we draw such a map? What territories would it span? What lines mark its boundaries?

Many approaches to evaluation are available to us, from both the hard and soft sciences. However, our particular task--facilitating communication in a group modeling context--inclines us toward the evaluation methodologies of the softer sciences.

One promising approach uses a systems framework to capture the essence of the modeling process.* By matching the characteristics of HUB with a given modeling task, we are able to determine the kinds of modeling efforts most likely to benefit from the HUB approach.

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*See P. B. Checkland, "The Development of Systems Thinking by Systems Practice--A Methodology from an Action Research Program," *Progress in Cybernetics and Systems Research*, vol. 2, Hemisphere Publishing Corp., 1975; Checkland, "A Systems Map of the Universe," *Journal of Systems Engineering*, vol. 2, no. 2, 1971; and Checkland, "Towards a Systems-based Methodology for Real-World Problem Solving," *Journal of Systems Engineering*, vol. 3, no. 2, 1972.

As a preliminary step toward building such a systems framework, we ask again the three questions suggested at the beginning of the second chapter:

What is being modeled?
Why is it being modeled?
How should it be modeled?

The range of responses to these questions constitutes a taxonomy of choices in the modeling process. When expanded, the questions provide a systems evaluation map of the modeling task.

In exploring *what is being modeled,* we will want to examine the modelers perceptions of the problem being modeled. Obviously, the modelers themselves may not be in unanimous agreement. To represent these perceptions in terms of our systems framework, we must determine: the goal or goals of the modeling task; the structure of the problem space; the activities or functions within that space; and the control or management dimensions of the problem.

It is important *to determine the final purpose,* or end use, of the model. The expected end use will affect both what sort of information is emphasized during the modeling process and how it gets transferred among modeling participants. End uses generally fall within one or more of the following categories: exploration or explanation of phenomena, prediction, planning, learning and teaching, and methodological development.

The crux of the actual modeling activity is *how it should be carried out.* Much material is available in this area, and a great number of protocols have been suggested. Our aim, during this evaluation process, is to suggest and enumerate the multitude of decision choices open to the modeler. Some of the issues that would be considered here can be found in the systems evaluation map in Table 1.

The framework we have outlined is certainly not a complete map of the modeling "space." But it begins to define a range of choices in the modeling process that may or may not be well suited to the HUB environment or that may affect the way that HUB is used in the modeling process. As we test HUB, we will be expanding and refining this map. We will try to locate both successful and unsuccessful uses of HUB. We will try to identify choices that seem to be critically linked to HUB. Through this evaluation, we hope to be able to answer the question that opened this report: What should we do with HUB now that we've got it?

TABLE 1: A SYSTEMS EVALUATION FRAMEWORK

WHAT IS BEING MODELED?

This category concerns the modeler's perceptions of the system being modeled, perceptions that might be organized according to:

- Structure
  - a complex or simple system?
  - an ill-defined or well-defined system?
  - a changing or stable system?
- Goals
  - to maintain stability?
  - to maximize order?
  - to minimize order?
  - to approach some "natural" end?
- Functions
  - single or multiple functions?
  - system-defining functions?
  - system-dependent functions?
- Control
  - controlled by internal forces not subject to change?
  - controlled by a few critical external decision points?
  - controlled by numerous, not well-known external decision points?

WHY IS IT BEING MODELED?

The expected end use of a model might be described in terms of one or more of the following categories:

- Exploration/explanation
  - to explain phenomena?
  - to identify causes of undesired system performance?
  - to understand operation of the system?
  - to provide input to another model or analysis?
- Planning
  - to explore alternatives?
  - to predict long-term effects of decisions?
  - to raise policy issues?
- Learning and teaching
  - to improve communication among actors in a situation?
  - to develop skills in decision-making in complex systems?
  - to learn to conceptualize a complex system?
  - to influence someone else's mental model?
- Methodological development
  - to develop a new modeling technique?
  - to test or demonstrate a new modeling technique?

HOW SHOULD IT BE MODELED?

Modelers make numerous choices about the way that a system should be modeled, including choices in the following categories:

- Organization
  - multisite or single site?
  - well-defined division of responsibility?
  - team approach, flexible division of responsibility?
  - short-term or long-term?
- Communication between builder and user
  - continuous or intermittent?
  - at beginning and end only?
  - written, telephone, face-to-face, computer-based?
  - formal presentations?
  - training?
- Communication among builders
  - highly structured or relatively unstructured?
  - face-to-face, telephone, written, computer-based?
  - graphics?
- Software choices
  - modeling language?
  - analysis packages?
  - interactive or batch?
  - display packages?
- Hardware choices
  - local computer?
  - network computer?
- Modeling techniques
  - numerical?
  - structural?
  - input-output?
  - econometric?
  - systems dynamic?
  - deterministic or probabilistic?

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